МОДЕЛИРОВАНИЕ СТРУКТУРЫ СЛИТКА НЕПРЕРЫВНОГО ЛИТЬЯ В ПРОГРАММЕ PROCAST

MODELING OF THE GRAIN STRUCTURE OF CONTINUOUS INGOT WITH PROCAST SOFTWARE

Dr inż. Marcin Janik (к. т. н. Марчин Яник)[1]
Prof. dr hab. inż. Henryk Dyja (проф. д. т. н. Хенрик Дыя)[1]
Prof. dr hab. inż. Andriy Burbelko (проф. д. т. н. Андрий Бурбелько)[2]
Prof. dr hab. inż. Wojciech Kapturkiewicz (проф. д. т. н. Войцех Каптуркевич)[2]
1) Czestochowa University of Technology, Faculty of Materials Processing Technology and Applied Physics, Czestochowa, Poland (Ченстоховский Политехнический Университет Факультет инжиниринга процессов, материалов и прикладной физики Отделение моделирования и автоматизации проессов пластической переработки)
2) AGH University of Science and Technology, Faculty of Foundry Engineering, Krakow, Poland
email: nemo@wip.pcz.pl

Краткое содержание

В работе представлены результаты численного моделирования роста внутренней структуры слитков в течение непрерывного литья стали. Для проведения исследований были выбраны две марки стали: марка A, предназначенная для прокатки листов, применяемых в кораблестроении, и марка S890QL, предназначенная для металлоконструкций повышенной прочности.

Для исследований использовалось коммерческое программное обеспечение ProCAST – CAFE, основанное на методе конечных элементов и ячеечных автоматах. Граничные условия были определены на основании измерений, проведенных во время разливки стали марок A и S890QL на польском металлургическом заводе "ISD Huta Częstochowa". Физические свойства разливаемых марок стали были определены на основании лабораторных испытаний и в программе ProCAST.

Во время моделирования были определены форма и величина зерен на разных этапах разливки. Для марки A результаты были сравнены со шлифованным образцом, вырезанным из слитка непрерывного литья и подвергнутым глубокому травлению.

Ключевые слова: непрерывная разливка стали, внутренняя структура слитка, ProCAST, CAFE

Introduction

Continuous casting of steel is the world's leading method of production of steel ingots [1]. Popularity of this method is affected by low production costs of steel, high quality product, repeatability of the parameters and smaller than other methods, a negative impact on the environment.

During continuous casting of ingot is formed crystalline structure, which determines the properties of the steel during metal forming [2]. Dendritic structure adversely affects the properties of the steel, the more preferred is fine equiaxed structure.

Numerical models allow to predict the crystal structure of the ingot for specific boundary and initial conditions of the process. There are many programs for the simulation of crystal growth. One of them is the software ProCAST - CAFE, based on the finite element method, and cellular automata [3, 4].

Numerical research

First, the research was conducted for steel grade A, which is dedicated to shipbuilding plates. Its chemical composition is shown in table 1. Research related to the continuous casting of ingots of 225x1300 mm cross section and the casting speed 0.9 m / min. Pouring temperature was 1535 ° C. The boundary conditions are defined on the basis of real process measurements and laboratory tests. Because the continuous casting process is symmetric, simulations were carried out for half of the ingot.

Table 1. The chemical composition of the steel grade A

C	Mn	Si	P	S	Cr	Ni	Cu	Mo	Nb
0.1500	0.4960	0.1880	0.0164	0.0138	0.0271	0.0619	0.1250	0.0196	0.0021
V	Al	N	As	B	Sn	Zn	Ti	Ca	
0.0010	0.0332	0.0093	0.0068	0.0001	0.0142	0.0072	0.0010	0.0003	

Figures 1 - 3 shows the structure of the steel ingot A grade at different stages of casting. At the outer edges of the slab, to a depth of several millimeters, the frozen structure is visible. Below the zone of frozen crystals appear dendritic structure, which reaches down to the middle of the slab and is the largest area of the ingot. Dendritic crystal width increases with increasing distance from the surface of the ingot. Equiaxed crystal zone appears in the center of the ingot and has a minimal width. Crystallization centers mainly appear on the front of solidification, in the liquid part of the ingot their share is negligible.

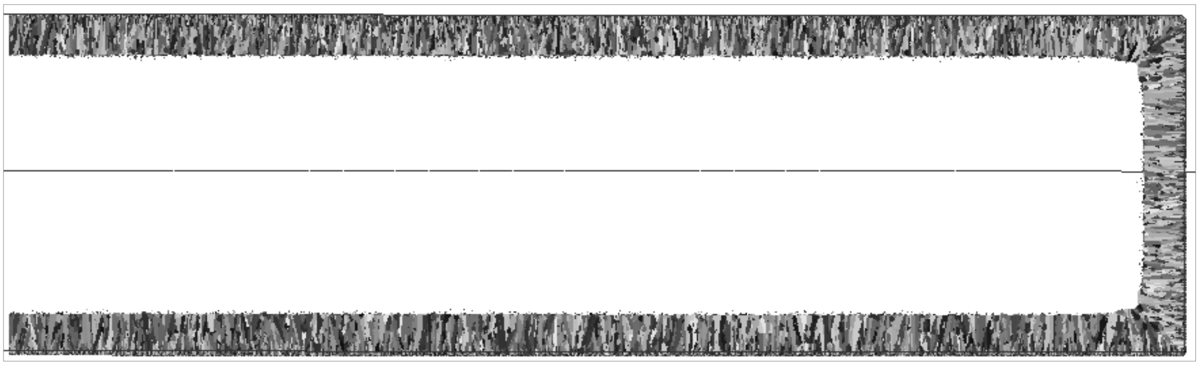

Fig 1. The grain structure of the steel grade A for mould exit zone

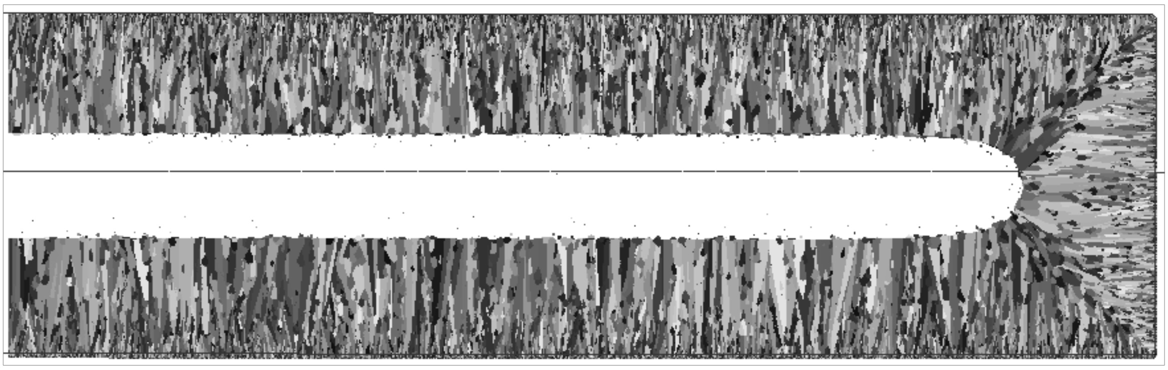

Fig 2. The grain structure of the steel grade A in the middle of the casting process

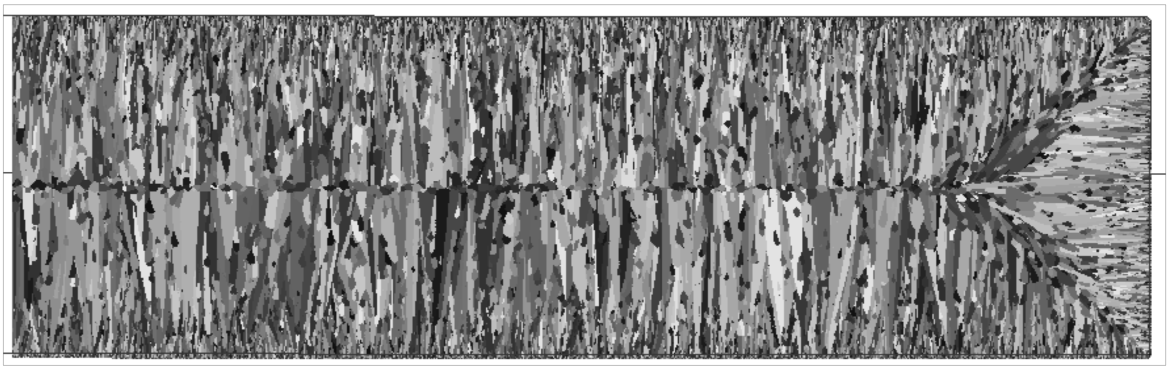

Fig 3. The grain structure of the steel grade A for casting machine exit zone

For verification of the numerical model were taken from ingot sample size 225x253 mm (steel grade A). The sample was then subjected to deep etching test in a solution of hydrochloric acid and sulfuric acid. Figure 4 shows the resulting structure.

As in the case of a numerical simulation, most of the area of the ingot dendritic crystals occupy the width of which increases with increasing distance from the surface of the ingot.

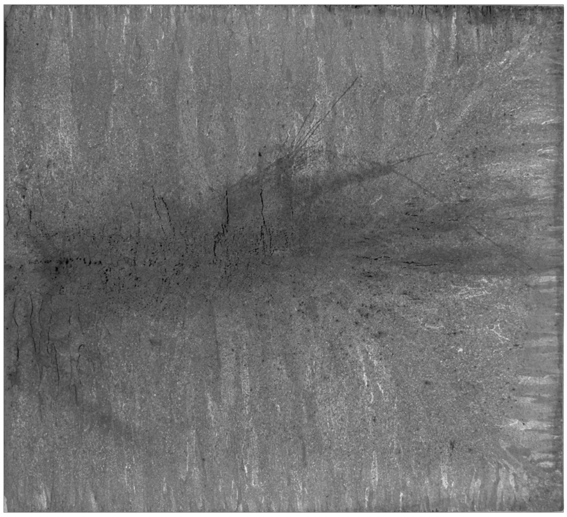

Fig 4. The deep etch test for the steel grade A

The next steel grade selected for the study was S890QL, dedicated for the high-strength structures. Its chemical composition is shown in table 2. Research related to the continuous casting of ingots of 225x1200 mm cross section and the casting speed 0.9 m / min. Pouring temperature was 1539 ° C.

Table 2. The chemical composition of the steel grade S890QL

C	Mn	Si	P	S	Cr	Ni	Cu	Mo	Nb
0.1700	1.1640	0.3720	0.0078	0.0026	0.4810	0.1060	0.1650	0.4680	0.0263
V	Al	N	As	B	Sn	Zn	Ti	Ca	
0.0493	0.0589	0.0090	0.0042	0.0025	0.0254	0.0013	0.0120	0.0023	

Figures 5 - 7 shows the structure of the steel ingot S890QL grade. Also in this case, on the outer edges of the slab, to a depth of several millimeters, the frozen structure is visible. However, definitely the largest area of the ingot is equiaxed structure. Equiaxed crystal diameter increases with increasing distance from the surface of the ingot.

If the ingot is located in the exit zone of the mould, the crystallization centers occur mainly on the front of solidification (fig. 5). In the middle of the casting process, a large number of crystallization centers also appear in the whole volume of the liquid core (fig. 6).

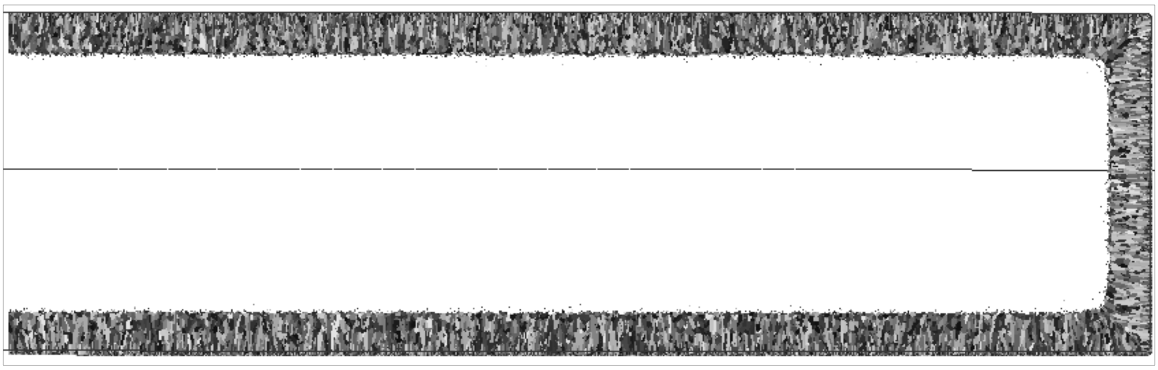

Fig 5. The grain structure of the steel grade S890QL for mould exit zone

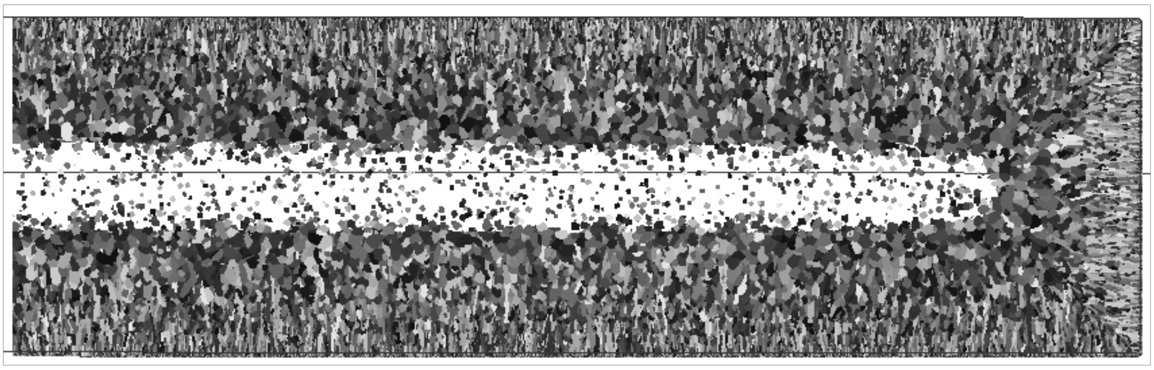

Fig 6. The grain structure of the steel grade S890QL in the middle of the casting process

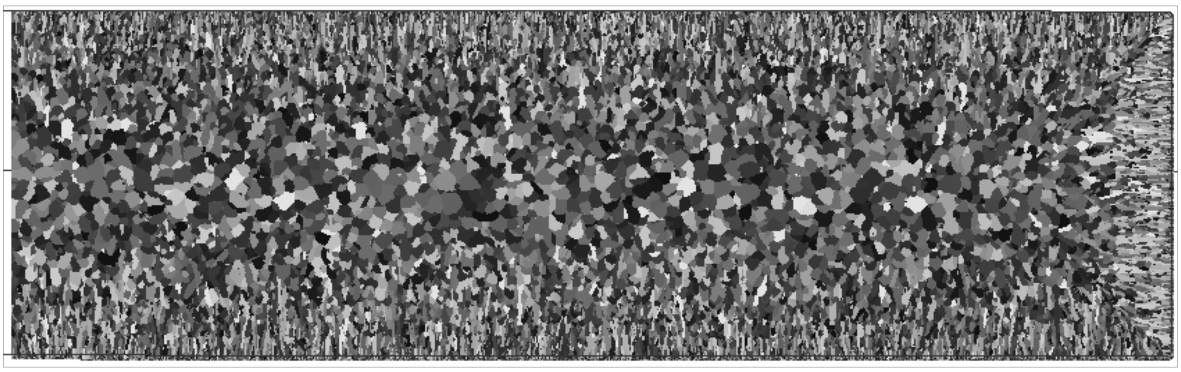

Fig 7. The grain structure of the steel grade S890QL for casting machine exit zone

Conclusions

This paper presents the results of structure formed during the continuous casting of billets for two grades, A and S890QL.

In the case of steel grade A, obtained dendritic structure, which is disadvantageous from the viewpoint of further metal forming processing. For steel grade S890QL received more favorable equiaxed structure.

Simulation results for steel grade A had been verified with the deep etching test, which confirmed the correctness of the calculations.

The use of specialized software ProCAST - CAFE, allows to quickly determine the structure of continuous cast billets for various grades of steel and various process parameters. As a result, it is possible to optimize the conditions of the casting process to improve the quality of ingots intended for further metal forming processing.

Literature

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